RESEARCH ARTICLE

Design of Smart Solar based Industrial Motor Monitoring and Control using Internet of Things

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ABSTRACT: Industrial Monitoring and Control is crucial for gathering all the significant data, statistics, and information on the numerous industrial processes, motors, machines, and equipment used in industrial facilities. This seeks to produce industrial goods with controlled access, increased productivity, and excellent quality. Remote control and monitoring using communication systems like ZigBee, RF, and infrared have become quite popular in industries in this new era of technological advancements. However, because to their sluggish communication speeds, long distances, and lack of data security, these wireless communication systems are typically limited to simple applications. Additionally, they are sensitive to noise and adverse weather, including snow, fog, and rain. In all of the GSM operator's service areas, security is possible without the requirement for a lot of physical infrastructure. In the present study, a new approach is taken to the smart solar based monitoring and controls of industrial applications through the installation of the Internet of Things (IOT) using GPRS enabled high quality connectivity, low cost, and high security without the need for extensive hardware infrastructure in all of the GSM operator's service areas. The stator voltage control approach has been used in conjunction with the Pulse Width Modulation (PWM) technique to achieve the required motor speed.

KEYWORDS: Internet of Things (IoT), GPRS,TCP/IP Protocol, GSM, Sensor module, Industrial application

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1. INTRODUCTION

Modern technological advancements have made it possible for automated and sophisticated systems to replace traditional ones. Additionally, the accessibility of sensitive, stable, and fast-processing items offered special advantages for industrial automation. As a result of advancements in communication technology, systems are now automatically monitored and controlled by computer-controlled or remote-controlled equipment rather than by staff utilizing traditional methods. The newly developed automatic approaches, industrial environmental circumstances have been improving day by day as a result of eliminating the traditional manufacturing processes that increased enormous workloads. This introduces the term "Smart Industries" to the new era of monitoring and regulating numerous industrial applications. Internet of Things (IoT) has received a lot of attention and is anticipated to have positive effects on a wide range of applications because it is an emerging technology that has accelerated improvements in contemporary wireless telecommunication [1].

The recently popularized idea of "Internet of Things" (IOT) is assisting in achieving industrial automation via remote access. Each device that makes up a system in the Internet of Things will be able to communicate with other devices or systems inside the same building using a common platform. Consequently, this results in the interchange of pertinent data, statistics, logs, and other parameter information among various devices to enhance their performance, which would aid enterprises in having improved production, management, and enhanced throughput. The main contribution of the research work to gather all the necessary data, statistics, and information on the numerous industrial processes, motors, equipment, and devices used in industrial facilities, industrial monitoring and control is crucial [2].

Different control technologies are used for monitoring and control the systems, whereas the communication between a system and a user is

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generally realized online via wireless communication techniques such as RF, ZigBee and Bluetooth. The SCADA programs are utilized for developing user interfaces. However, SCADA programs do not provide adaptability for users because of their expensive libraries. RF, ZigBee and Bluetooth technologies are widely preferred in easy-to-use applications due to the short range between the sender and the receiver, and the small volumes of data transferred. The ZigBee, RF and Bluetooth wireless communication techniques are generally restricted to simple applications because of their slow communication speeds, distances and data security [3].

Nowadays, timer controlled systems with their low costs, durability, high power, and minimal maintenance requirements, motors (IM) are widely utilized in residential appliances, industrial equipment, automotive, aerospace, and the military [1]. Single-phase induction motors (SPIMs) drive a fan, pump, or compressor type of load, including its uses in heating, ventilation, and air conditioning, and account for the majority of the electric power utilized globally [2]. Historically, motor-driven systems have been intended to give a load margin of 20–30% above the entire load value for an extended period of time. They typically operate at a virtually constant speed. The motors can be run at a speed that produces the desired regulated outputs to prevent this wasted energy. As speed is reduced, the input power also drops. It is possible to predict this drop by understanding that in an industrial motor (4).

$$\text{Torque} \sim k_1(\text{speed})^2 \qquad (1)$$

$$\text{Power} \sim k_2(\text{speed})^3 \qquad (2)$$

where k 1 and k 2 are the constants of proportionality.

Recently, the timer controlled systems have been easily replaced with remote controlled systems after the internet became widespread. Obtaining information via the internet about both the control and the state of a machines or equipment is regarded as a crucial concern in these systems. In accordance with this need, there are some works about implementation of condition monitoring of system through internet and development of internet-based remote controlling or monitoring practices. There are some successful examples such as PLC SCADA based fault detection and protection system is implemented which provides the web based user interface for remote control and monitoring was developed and presented online to users. The ZigBee protocol has been adapted to monitor a variety of industrial characteristics, including temperature, water level, and different current and voltage ratings [5].

Modern industries are moving more and more in the direction of automation. Remote system access, monitoring, and control are now available due to the increasing use of the internet [3]. Internet of Things technology is advancing quickly, enabling a collection of physical objects or things to communicate with one another and be controlled by computers [6–7]. Through the use of wireless devices, sensors, and web-based intelligent operations, IoT has offered a promising means to develop robust industrial automation [8]. Diverse research, design, and implementation efforts have been made for web-based systems for controlling and monitoring single-phase induction motors using solar [9].But the proposed methods are not suited to traverse a greater distance due to ZigBee slow data rate and high cost. A wireless monitoring system for three phase induction motor is realized using ZigBee protocol to reduce the human hazards for safe and economic data communication in industrial fields [10].The wireless speed management of instant messages (IMs) utilizing GSM, Bluetooth, and Wi-Fi technology includes fewer communication functions were reported [11]. By describes the development of an IoT-based IM monitoring system based on the analysis of sensor data gathered from local and remote servers, a Wi-Fi equipped Raspberry Pi, and a web application. In order to fill this gap, this study offers a straightforward web-based communication method for the bidirectional speed control and monitoring of several single-phase induction motors. The stator voltage control approach employing the pulse width modulation (PWM) methodology has been used to control the speed of induction motors by using chopper [12,13]. The present study aims to design microcontroller based LCD to monitor the prototype design parameters, which are transmitted via GPRS were discussed. This makes the system more adaptable and eco-friendly.

2.PROPOSED SYSTEM

Industrial monitoring and control is a mix of architectures, methods, and algorithms that are used in industrial factories to monitor and control the operations of industrial processes, motors, machines, and devices used in industrial premises to achieve the aim. A smart industrial environment may seem fantastic, but it will also have to deal with huge data handling challenges since all the devices would communicate with one another and share information over a shared platform [14]. The current research is concentrated on industrial applications that will be continuously tracked by a group of sensors that make up a sensor module. When specified threshold values are met, the sensor module gathers the pertinent data to assess how well the monitored apps are performing.The data from various sensors in the sensor module is fed to the controlling device basically a microcontroller. This controlling device is interfaced with a GPRS enabled GSM module to get accessed remotely by users shown in Figure 1. The controlling device simultaneously forwards data to the main server. The main server located at the industry premises displays the corresponding data received from the controlling device. An arrangement of accessing the main server remotely by mobile users can be achieved through TCP/IP protocol, thus monitoring of the applications can be done through remote access. Figure 2 shows the basic Block diagram of IOT based motor monitoring and controlling.

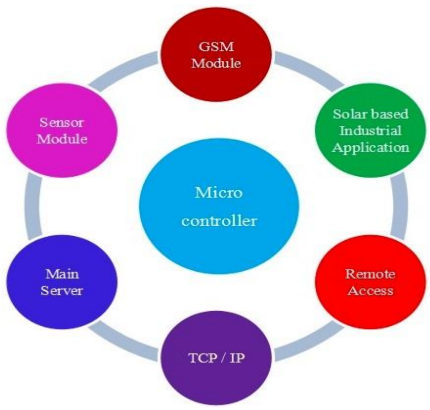

Figure 1: Basic Schematic Diagram IOT

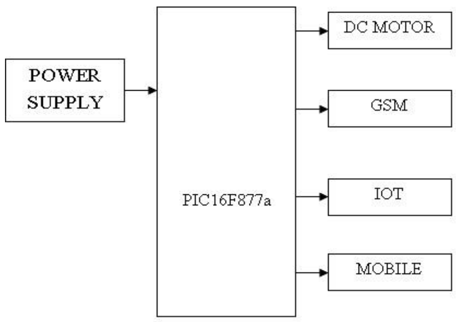

Figure 2: Block diagram of IOT based motor monitoring and controlling

3. EXPERIMENTAL SETUP

A laboratory prototype of IoT based bidirectional speed of Industrial induction motor design was fabricated by using the design of DC motor control based on IoT Nodes with routers. There are 4 components in the system. The DC-DC Converter is the initial component, to supply the motor with 25V. The PID algorithm is used in this study to manage the speed of a DC motor. The DC motor is controlled by using smartphone device using IoT nodes. The nodes are used to connect the internet and communicate by using routers. The final step is node-by-node data transfer. However, this study covers one node, which examines IoT-based DC motor control. The solar panel's output voltage is set to 10 volts DC, and this provides power to the Node-MCU. The Node-MCU performs control and data transmission to the internet functionalities. The water pump utilized is a 10 m^3/h, 24 volt DC pump that rotates at a speed of 3600 rpm [17]. Although the power on the solar cell drops, the pump's motor speed needs to remain stable. By using DC-DC converter to raising the voltage, the converter may also stabilize the voltage produced by solar cells to monitor the motor speed and maintain the temperature. A laboratory prototype of IoT based Smart Solar based Industrial Motor design was fabricated is shown in Figure 3.

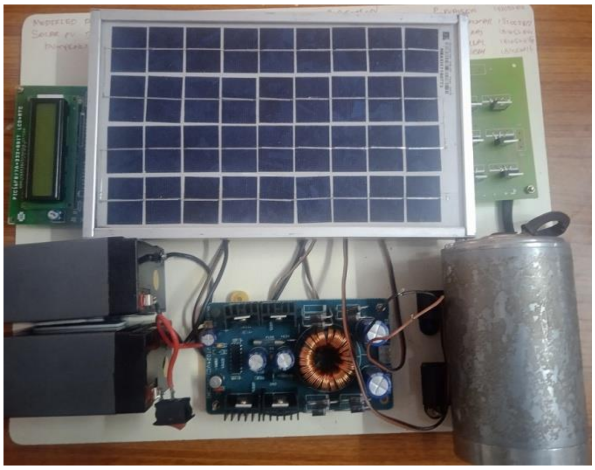

Figure 3: A laboratory prototype of IoT based Smart Solar based Industrial Motor

An electric motor is a mechanical device that converts electrical energy towards mechanical energy. The inverse of this is performed because of an electric generator that changes electrical energy into mechanical energy. Most electric motors generate force inside the motor during normal driving mode by interacting with the magnetic field and winding currents. In some application fields, such as in the transport industry to traction motors, industrial fans, pumps and blowers, machine tools, home appliances, power tools, and disc drives, electric motors can be powered by direct current (DC) sources like batteries, motors, or rectifiers or by alternating current (AC) sources like the power grid, inverters, generators, Electric watches may contain small motors [15].

The largest electric motors, having 100 megawatt capacities, are used for pipeline compression, ship propulsion, and pumped storage. Electric motors can be classified depending on their internal structure, intended usage, output type of motion, and other elements. Electric motors are used to generate linear or rotary force, in opposition to devices such magnetic solenoids and loudspeakers that convert energy into motion but do not deliver meaningful mechanical powers [15].

3.1 Motor Construction Rotor

The rotor, that turns the shaft inside an electric motor to generate mechanical power, is its moving component. In most cases, the rotor includes conductors built into it that transport currents that react with the stator's magnetic field to produce the forces that turn the shaft. Some rotors do, however, contain permanent magnets, as well as the stator is where the conductors are kept (15).

3.2 Stator

The stator, which is the stationary component of the electromagnetic circuit of the motor, often is made up of winding or permanent magnets. Lamination or several thin metal sheets, make up the stator core. By using lamination instead of a solid core, energy losses that would normally occur are reduced [15].

3.3 Air Gap

The air gap is the separation between the rotor and stator. Since a wide gap has a significant detrimental impact on the operation of an electric motor, the air gap has significant impacts and is often as small as possible. The low power factor at which motors run is primarily caused by this. The amount of magnetizing current required rises with the air gap. Along with noise and losses, extremely narrow gaps may also cause mechanical issues. Salient-Pole Rotor consists of thicker metal, such as bars or sheets of metal, usually copper, although sometimes aluminum is used. These are usually powered by electromagnetic induction [15].

3.4 Commutator

A commutator is a device that switches the input of the majority of DC machines and some AC machines. It is made up of slip ring sections that are insulated from one another and from the shaft of the electric motor. Electromagnetically commutative motors have made great strides and result of improved technology in the electronic controller, sensor less control, induction motor, and permanent magnet motor domains (15).

3.5 Motor supply

A slip ring commutator is typically used to supply a DC motor. Commutation for AC motors can be externally or internally commutated, fixed-speed or variable-speed controlled, and synchronous or asynchronous in nature. Both AC and DC can be used to power universal motors.

3.6 Motor Control

Fixed-speed controlled AC motors are provided with direct-on-line or soft-start starters. Variable speed controlled AC motors are provided with a range of different power inverter, variable-frequency drive or electronic commutator technologies. The term electronic commutator is usually associated with self-commutated brushless DC motor and switched reluctance motor applications [15].

3.7 GSM Modem

A wireless modem that operates with a GSM wireless network is known as a GSM modem. Similar like a dial-up modem, a wireless modem operates. The fundamental distinction between both is that a wireless modem uses radio waves to send and receive data, whereas a dial-up modem uses a fixed telephone connection. The GSM modem relies on commands to function and each command must begin with AT (which stands for ATtention) and end with a CR character. With the aid of a PC or controller, AT commands are sent to the GSM modem. With the aid of MAX 232, the GSM modem is sequentially interfaced with the controller. Here, the driver, max 232, transforms TTL levels to RS 232 levels. The signal depending on RS 232 levels is necessary for the serial interface of a GSM modem. The TX and RX pins of the GSM modem are linked to the T1 OUT and R1 IN pins of MAX 232 [16].

3.8 GSM Security

GSM was designed to be a safe wireless network. It has taken into account over-the-air encryption as well as user authentication utilizing a per-shared secret and challenge-response. GSM is however susceptible to various attack types, each of which targets a different area of the network. The development of UMTS brings an additional Universal Subscriber Identity Module (USIM) that, in contrast to GSM, jointly authenticates the network and the user while using a longer authentication key to provide higher security (and not vice versa) (16).

3.9 Key Features of IoT

Artificial intelligence, connection, sensors, active involvement, and the usage of small devices are the IoT's key characteristics. AI-IoT effectively transforms everything into a "smart" object by leveraging data collecting, algorithms for artificial intelligence and networks to improve every area. Connectivity–Networks are no longer only dependent on big providers because to new networking enabling technologies, particularly IoT networking shown in Table 1. Networks are still useful even when they are much smaller and less expensive. The IoT creates these small networks between its system devices Sensors IoT loses its distinction without sensors. They serve as defining tools that turn the IoT from a conventional passive network of devices into an active system that can be integrated into the actual world. Active Engagement-Passive engagement accounts for the majority of interactions with linked technologies today. A paradigm shift for participating in physical activities, product, or service interaction is introduced by IoT. The devices have gotten smaller, more affordable, and more potent over time. To achieve its accuracy, adaptability, and flexibility, IoT makes use of specially designed tiny devices [16].

Table 1: Comparison of wireless communication techniques

Characteristics	Zigbee	GPRS	Wi-Fi	Bluetooth	RF
System Resource	4-32 Kb	16Mb+	1 Mb+	250Kb+	32kb
Network data width(kb/s)	20-250	64-128+	11000+	720	32
Coverage Area(meter)	1-100	1000+	1-100	1-10+	1-100+

Solar PV Module Specification

In this work, DC motor loads are powered by solar modules. The ECO LINE P/300-355 W Parameters of the COPEX M250 module 25°C and 1000 W/m2 Module was utilized in the creation of this project. These are the solar module's specifications.

Table 2: Solar PV module Specification

For a PV Module	
Parameter	Value
Maximum Power (P_{max})	50 Wp
Voltage @ Pmax (V_{mp})	3.14 A
Current @ Pmax (I_{mp})	21.4 V
Open-circuit Voltage (V_{oc})	2.88 A
Short-circuit Current (I_{sc})	17.4 V
Maximum System Voltage	1000V_{dc}

3. RESULTS AND DISCUSSION

The application of IoT is used in different domains, for example monitoring of industrial motor loads. Additional information such as motor's temperature, over voltage, and speed are also monitored. In the present study, loads are monitored and managed using a GSM module and the Internet of Things. Several parameters are implemented through a Smartphone using the ARDUINO IDE programme and the MQTT application (14). Figure 3 illustrates the use of IoT technology in a laboratory setting to control and monitor various SPIM's speed and direction. A remote operator can view the system and ensure whether the motors are operated as intended.

Using Thinkspeak and Blynk IoT software, the speed of a DC motor and its functions are monitored and controlled regularly. The function of Boost Converter is to increase the voltage values; it is unable to lower the reference voltage whenever the output voltage is more than 24 volts. Motor Speed is affected by output voltage results. The input data from the user is a crucial parameter in addition to the information from the output voltage sensor. The user's input data includes the intended motor speed value. Using the EMF approach, the motor speed data is transformed into voltage data, which is then used as a set point to create PWM signals. Every 15 seconds, Thingspeak sends the monitored data to the web, while continually processing the data for PWM with temperature, gas sensor monitoring, and rotation fan status and vibration. Based on this study, the proposed system provides ON/OFF control, rotation control clockwise (CW) and counter-clockwise (CCW) directions, and speed control as 75% of related speed.

The micro controller processes the motor characteristics that were obtained from the IR sensors and sends them through GPRS to a remote computer or mobile device as well as displays them on an LCD for field operators. The result obtained is used to investigate the industrial induction motor to maintain and control 25 degree temperature with 30 minutes of time duration (Figure 4). The gas sensor is used to measure the previous environmental parameters within the same time to control the motor fan reported (Figure 5). The fan motor speed result is used and put through its paces using speed input values from a smart phone as shown in Figure 6. Monitor control and vibration have been noticed in the web server and LCD with regard to the variation of the PWM duty cycle (Figure 7). These findings demonstrated that a user's smart phone can be used to turn on a fan and control its speed with vibration as shown in Figure 8.

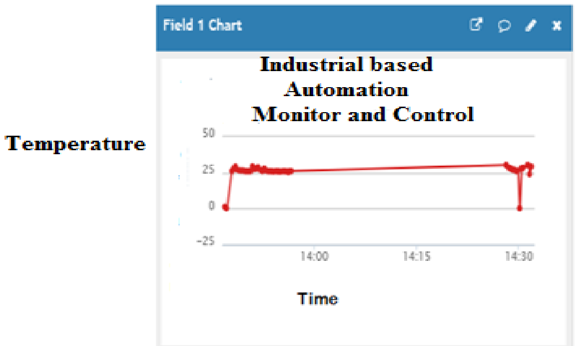

Figure 4: Temperature monitoring

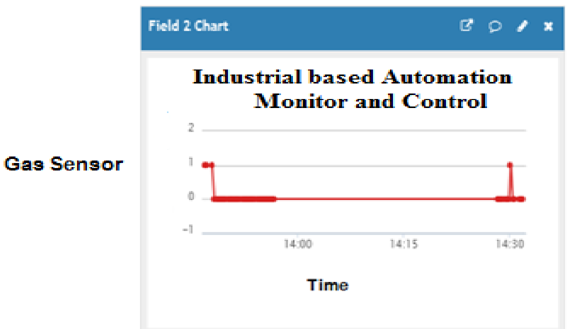

Figure 5: Gas sensor monitoring

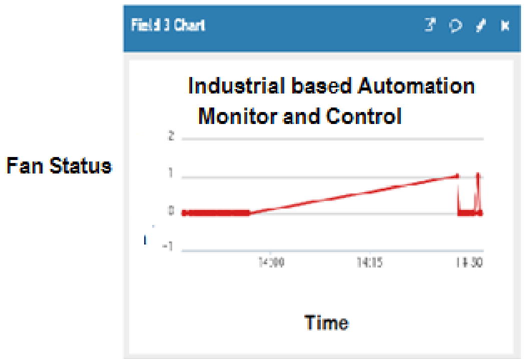

Figure 6: Fan status monitoring

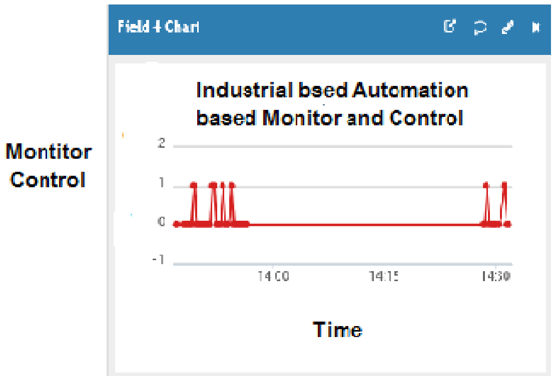

Figure 7: Motor Control monitoring

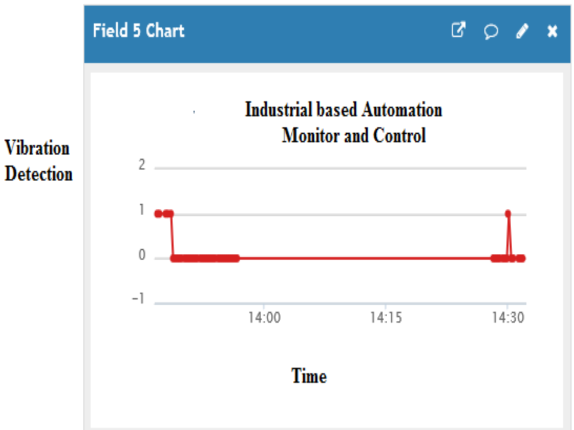

Figure 8.Vibration Detection monitoring

A lightweight open messaging protocol called MQTT (MQ Telemetry Transport) gives network motor speed monitoring and control with limited resources which is an easy way to share telemetry data in low-bandwidth settings as shown in Figure 9 and Software program using Blynk App of speed control as shown in Figure 10.

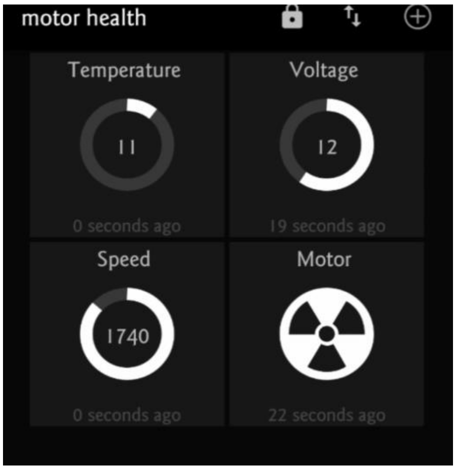

Figure 9: MQTT Display

Figure 10: Software program using Blynk App using industrial motor control

CONCLUSION

The smart solar-powered IOT-based Motor Monitoring System has been successfully implemented. The proposed system was tested and found to be functional according to industry standards. The system was created in order to modernize the outdated security methods into an IOT system that is practical to monitor and access. There is no need to move when monitoring the motor from a stationary position. This system is just utilized to monitor the on/off functionality and maintain surveillance on the motor working state. The efficiency of the system is increased with the prevision of a warning signal when there is a problem. A user-friendly and convenient platform is provided to the user via the graphical App-based mobile controlling. Utilizing the internet or a Wi-Fi connection, the user can access data from a distance. Further studies are in progress to understand remote monitoring in industrial automation.

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